Virginia Department of Environmental Quality

Quality Assurance Plan for the Virginia Mercury Study

April 6, 2007

07-024

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Virginia Department of Environmental Quality

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Prepared for
Michael Kiss
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 23219
(804) 698-4460
mfkiss@deq.virginia.gov

Prepared by:
ICF International
101 Lucas Valley Road, Suite 260
San Rafael, CA 94903
(415) 507-7164
jhaney@icfi.com

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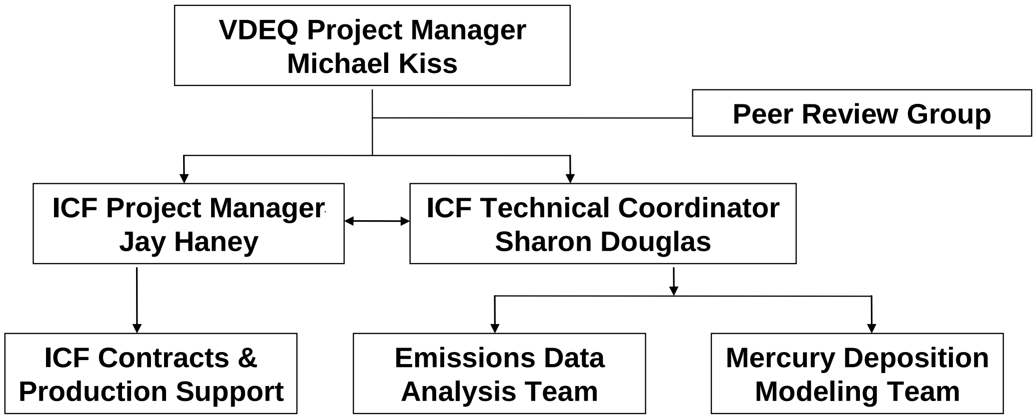
Table of Contents

1. Project Management

1.1. Project Organization

This project is being funded and managed by the Virginia Department of Environmental Quality (VDEQ). The technical analysis, including the mercury emissions data analysis and the mercury deposition modeling is being conducted by ICF International. The overall project organization and communication structure is presented in Figure 1-1.

Figure 1-1. Project Organization Chart for the Virginia Mercury Study.



1.2. Background

Human exposure to mercury is most commonly associated with the consumption of contaminated fish. Due to measured high levels of mercury in fish, at least 44 U.S. states have, in recent years, issued fish consumption advisories. These advisories may suggest limits on the consumption of certain types of fish or they may recommend limiting or not eating fish from certain bodies of water because of unsafe levels of mercury contamination. States have identified more than 6,000 individual bodies of water as mercury impaired and have issued mercury fish advisories for more than 2,000 individual bodies of water.

Until 2002, significant mercury contamination in Virginia surface waters was known only in three rivers (the North Fork of the Holston River, the South River, and the South Fork Shenandoah River) with historical industrial releases. Since then, however, state monitoring efforts have identified mercury contamination in a number of surface waters without readily identifiable sources.

Virginia expanded its mercury monitoring in 2002 based on an increasing scientific understanding of mercury's environmental chemistry and discoveries in other states (e.g., Florida, Maryland) of mercury pollution in water bodies without direct sources. The 2002 monitoring effort focused on rivers of the coastal plain, mostly to the east of I-95. As a result of this effort, Virginia found elevated mercury levels in some fish in the Blackwater River, the Great Dismal Swamp Canal, the Dragon Run Swamp, and the Piankatank River. Consistent with findings from Florida and elsewhere, these water bodies in Virginia possess characteristics favorable for the formation of the highly bio-accumulative form of mercury, methyl mercury. These characteristics include low dissolved oxygen, high organic matter, and low pH, and are most prevalent in "backwaters" of the southeastern portion of the state.

The primary source of mercury to these water bodies is suspected to be atmospheric deposition. There are currently three Mercury Deposition Network (MDN) sites located in Virginia, in Shenandoah National Park, Culpeper, and Harcum and data from these sites have contributed to the regional characterization of mercury transport and deposition throughout the state. Additional monitoring at the Harcum site in 2005 revealed that dry deposition of reactive gaseous (divalent) mercury along the Piankatank River (near the Chesapeake Bay) and in upstream areas is an important contributor to the high mercury levels observed in the water and fish in the area.

Global, regional, and local sources of air mercury emissions contribute to the deposition, and understanding these contributions is an important step toward identifying measures that will effectively reduce mercury deposition and environmental mercury levels.

1.3. Project Description

The Virginia Mercury Study comprises two major work areas: mercury emissions data analysis and mercury deposition modeling.

1.3.1. Mercury Emissions Data Analysis (Section A)

The data analysis focuses on the review and refinement of the mercury emissions data from a variety of source categories, which include coal-fired utilities, medical waste incinerators, and municipal waste incinerators. The emissions data analysis also requires the reliable projection of these data to three future years, accounting for the requirements of the Virginia General Assembly Bill that limits participation by sources located in Virginia in the mercury emissions federal trading program. The reliability of the mercury deposition assessments, including the modeling, will depend significantly on the quality and completeness of the emission inventory data. Thus, a key objective of the emissions data analysis component of the study is to assess and improve, as needed, the reliability of the mercury emissions data.

The technical tasks in this work area include: 1) air point source mercury emission inventory review, 2) mercury emission inventory summary, 3) literature review, 4) preparation of a mercury emissions data analysis report, and 5) data archival and transfer of inventory files.

1.3.2. Mercury Deposition Modeling (Section B)

The modeling analysis includes the development of a conceptual description of mercury deposition, which will improve the overall understanding of the mercury problem and the relationships between meteorology and mercury deposition. It also includes the application of grid-based and Gaussian models to simulate mercury deposition. The modeling results will provide a basis for quantifying the contribution of emissions sources to mercury deposition and examining the fate of mercury emissions from selected sources. For environmental planning purposes, the modeling will be used to examine the effectiveness of control measures in reducing mercury concentrations in contaminated bodies of water and improving or maintaining water quality within the designated areas of interest in Virginia. By quantifying deposition, the modeling results will also provide a link between the analysis of mercury emissions and the assessment of the impacts of airborne mercury on fish tissue and human health.

The technical tasks in this work area include: 1) development of a conceptual model, 2) preparation of a modeling protocol, 3) model sensitivity analysis, 4) model performance evaluation, 5) modeling simulations, 6) preparation of a mercury deposition modeling report, and 7) data archival and transfer of modeling files.

1.4. Quality Objectives and Criteria

Quality objectives for the project address several areas: data acquisition, processing, and analysis; emission inventory processing; model input acquisition, review and preparation; model application; postprocessing procedures; data archival and transfer; and documentation.

The data include emissions data (for review and for the preparation of model-ready emission inventories), meteorological data (for the development of the conceptual model and the development of meteorological inputs for the Gaussian modeling), land-use data (for the development of land-use inputs for the Gaussian modeling), and mercury data (for development of the conceptual model and model performance evaluation). The quality objectives for the data acquisition, processing, and analysis steps are to confirm that 1) all data are obtained from a reliable source, 2) all electronic transfers are complete and error free, 3) all datasets are complete and that error flags (if included) are defined and understood, 4) missing data are properly identified, 5) units and other identifiers are correctly assigned, 6) data values are within reasonable ranges, and 7) all data processing steps are performed correctly. All data and data processing steps will be carefully checked to ensure the utility of the data.

The quality objectives for the modeling related tasks (input file acquisition/preparation, model application, and postprocessing) are to ensure that all software is applied correctly, and all input and output files are error free.

The quality objectives for data archival and transfer tasks are to develop and maintain comprehensive archives of the data and model-related files, avoid any loss of information due to computer related problems that may arise during the course of the study, and to successfully transfer all files to VDEQ.

All documentation will be checked for errors and inaccuracies. Internal and external review will help to ensure the quality of the documentation and that the conclusions are well reasoned, scientifically sound, and consistent with the data analysis and modeling results.

1.5. Special Training/Certification

No special training or certification is required to complete this project.

1.6. Documents and Records

In addition to this quality assurance plan, other project documents include: (1) project work plan, (2) memoranda summarizing the emissions data analysis and literature review tasks, 3) draft and final versions of an emissions data analysis report, 4) modeling protocol, 5) memoranda summarizing the mercury deposition modeling tasks, and 6) draft and final versions of the mercury deposition report.

All documents prepared as part of this project will continue to be available from ICF for a minimum of five years.

2. Assessment and Oversight Elements

The majority of the technical work will be conducted by ICF and VDEQ will provide assessment and oversight. Ms. Diane Shotynski of Thruput and Mr. Tim Lavallee of LPES, Inc., both Virginia based consultants, will assist with the literature search and the emission inventory assessment and will report directly to ICF.

2.1. Assessments and Response Actions

Bi-weekly conference calls will be held throughout the project to review project status, discuss technical issues and/or the resolution of technical difficulties. If problems are identified and corrective actions are required, ICF will make the corrections to the approach or work product and document any such corrections in the project report.

The QAPP will be updated and revised as necessary during the course of the project.

2.2. Report to Management

ICF will provide VDEQ with monthly progress reports summarizing work accomplished during the reporting period, problems encountered and how they were resolved, planned activities for the next reporting period, and status of deliverables. The monthly progress reports will also include a summary of expenditures for the period and cumulative expenditures for the project.

3. Data and Input File Acquisition, Review and Processing

3.1. Emissions Data and Input Files

Point source mercury emissions data for Virginia have been obtained from VDEQ. Our review of the Virginia point source emissions data will serve as the quality assurance of these data. We will conduct a thorough technical review of the emissions estimates, taking into account the important factors that affect mercury emissions such as process-type, boiler-type, fuel type, equipment-type, and stack parameters (e.g., flow rate, exit temperature, exit velocity, etc.). For each facility, we will assess the accuracy of the emission estimates and review all of the facility-specific information including location, stack parameters, hours of operation, maintenance schedules, and estimated diurnal operating profiles.

Any missing or questionable information will be reported to VDEQ and updated/corrected if possible. Any changes to be made to update the Virginia point sources will be reviewed and approved by VDEQ staff prior to use in the modeling analysis.

For the remaining geographical areas and source categories, we will use emissions data from version 3 of the 2002 National Emissions Inventory which has been obtained from EPA. For the NEI, our review will also focus on identifying missing or erroneous information and making corrections where possible.

We will assess the inventory to ensure that the minimum data requirements and quality standards are met. The types of issues that will be addressed include the following:

- Inclusion of all required components (i.e., point, area, on-road motor vehicle, non-road motor vehicle, and natural emissions).
- Geographical coverage of the inventory (emission estimates should be provided for all counties in the modeling domain, not just the counties located in the actual study area).
- Assessment of completeness of database (identification of default or missing values for inventory parameters such as source location, stack parameters, operating schedules, etc.).
- Inclusion of existing regulatory requirements, including rule effectiveness and rule penetration factors for applicable sources and source categories.

For both sets of emissions data, we will use tabular and graphical methods to review and evaluate the emissions. We will prepare tabular summaries of the mercury emissions by state and by source category and will plot the point source emissions to check the locations of the facilities.

Model-ready emissions for the application of the Community Multiscale Air Quality (CMAQ) model will be prepared using the Sparse Matrix Operator Kernal Emissions (SMOKE) emissions preprocessing system. To ensure the correct execution of SMOKE, we will review all run scripts and check and log all error messages. We will use the SMOKE emissions summary features to check that the resulting emissions are consistent with the input emissions data with regard to the amount and type of emissions.

ICF will verify that the specified input and output files for each processing step contain the appropriate information required to process the emissions data in the expected manner. Temporal profile assignments for each source category, including seasonal, weekly, and diurnal variations will be reviewed. The spatial allocation surrogate data and surrogate assignments for each source category will also be examined. ICF will ascertain that all required processing steps have been completed in an appropriate order and will track input and output emissions totals for each processing step to identify any gross errors in processing.

Once the model-ready emissions have been prepared, further quality checks will be applied. These will include:

- Cross checks of emissions totals in the inventory data files compared to the CMAQ-ready input files. These types of checks will be used to ensure that the processing does not result in emissions being left out of the inventory and that there were no errors in converting the units of emissions.
- Displays of emissions density of area sources. These displays will be used to check for spatial inconsistencies in the emissions.
- Plots of point source emissions by emissions category and by individual state. These displays will be used to confirm that the elevated point sources of mercury are located within the correct state and at the correct location.

To facilitate the quality assurance and review of the emissions inputs, the following tabular and graphical summaries will be prepared and examined:

- Plots illustrating the magnitude and spatial distribution of low-level emissions of mercury (by component, total anthropogenic, and total anthropogenic and geogenic).
- Plots illustrating the magnitude and spatial distribution of elevated point-source emissions of mercury.
- Plots illustrating the temporal distribution of low-level emissions of mercury (by component, total anthropogenic, and total anthropogenic and geogenic).
- Plots illustrating the temporal distribution of elevated point-source emissions of mercury.
- Tables summarizing emissions totals (by component, total anthropogenic, and total anthropogenic and geogenic) for each CMAQ grid.
- Tables summarizing emissions totals (by component, total anthropogenic, and total anthropogenic and geogenic) for each state in the modeling domain.

For the future-year emission inventories, the review will focus on the control assumptions and projection factors used to estimate future year emission rates. We will verify that the emissions changes are consistent with expected controls and emissions changes, and, in particular, CAMR and the Virginia state-specific rules. We will prepare emissions difference plots displaying the differences between the future-year and base-year emissions to aid our quality assurance of the future-year emissions processing.

Use of the CMAQ Particle and Precursor Tagging Methodology (PPTM) requires the preparation of additional modeling emission inventories in which selected emissions sources, source categories, or source regions are tagged. We will use spatial plots to confirm that the tags are applied at the correct source locations.

Emissions for the Gaussian model (AERMOD) will be prepared for selected sources using the point source data provided by VDEQ. The input emissions data will be cross checked against the original emissions data. For the future-year, differences between the future-year and base-year emissions for each facility will be verified to be consistent with expected controls and emissions changes.

3.2. Mercury Data

Mercury deposition data for use in the data analysis and the model performance evaluation will be obtained from the Mercury Deposition Network (MDN) dataset as available on the National Acid Deposition Program (NADP) web site (www.nadp.sws.uiuc.edu). For the data analysis, mercury wet deposition data for all sites within Virginia and several nearby and surrounding states (North Carolina, Tennessee, Kentucky, West Virginia, Pennsylvania, Maryland, Delaware, and New Jersey) will be obtained for the period 1996-2006, as available. For most sites, the data record begins in 2000 or later. For the CMAQ model performance evaluation, mercury deposition data will be obtained for all sites within the modeling domain for the 2001 base year and for the 2002 alternative base year. These data will be reformatted and processed for use in the respective analyses. The following is a list of actions that will be undertaken to ensure the reliability of the underlying data from the MDN database.

- For each monitoring site, the site codes will be checked to verify the State and county.
- The units for all data elements and for all sites will be confirmed.
- Once the files have been reformatted and/or processed for use in the data analysis and modeling tasks, randomly selected values in the reformatted, processed data files will be cross-checked against the original data files for accuracy.
- Mercury wet deposition values for each site will be extracted and sorted according to magnitude, to check the range of values for reasonableness (e.g., that all concentration values are positive) and the completeness of the dataset (i.e., that missing values are accounted for and properly indicated).
- The quality-assured data files will then be passed from the person responsible for the data extraction, reformatting and processing to the data analysts/modelers. The analysts/modelers will then perform a second check of the values for range of each variable, format of the file, and completeness.

3.3. Meteorological Data and Input Files

Meteorological data for use in the data analysis (conceptual description) and AERMOD input preparation tasks will be obtained from the National Climatic Data Center (NCDC) (www.ncdc.noaa.gov). The data will include surface and upper-air meteorological data for the period 2000-2005 for sites in Virginia and several nearby and surrounding states. The following procedures will be followed to ensure that the data are of sufficient quality and prepared correctly for use in the data analysis.

- The units for all data elements and for all sites will be confirmed.
- The range of time over which the data are available and the timestamp for each data element will be reviewed. This is done to ensure that the data cover the full period time of interest, and avoids problems such as those associated, for example, with data gaps and/or leap years.
- Once the files have been reformatted and/or processed for use in the data analysis and modeling tasks, randomly selected values in the reformatted, processed data files will be cross-checked against the original data files for accuracy.

- The formulas used to calculate data-derived quantities will be check and several randomly selected values will be checked by hand. An example of a data-derived quantity is temperature difference between the surface and the 850 mb level (which is an indicator of stability).
- The values of the meteorological parameters for each site will be sorted according to magnitude, to check the range of values for reasonableness (e.g., that all values are within expected ranges for each parameter) and the completeness of the dataset (i.e., that missing values are accounted for and properly indicated).
- Data records will then be checked for completeness particularly with respect to values at the beginning and end of data periods (e.g., months, years, and full periods, as well as values for February 29th.)

CMAQ-ready meteorological input fields for the 2001 base year have been obtained from EPA. The same set of meteorological input fields will be obtained for the 2002 alternate base year, also from EPA. Since these input files have been prepared and reviewed by EPA personnel, we do not expect to conduct significant further quality assurance. However, we will prepare selected plots and summaries of the meteorological inputs to aid our interpretation of the CMAQ modeling results and to ensure the integrity of the meteorological datasets.

Meteorological inputs for the application of AERMOD will be prepared using the AERMET preprocessor program. In setting up and applying AERMET, the quality assurance check will focus on:

- Establishing the most appropriate meteorological monitoring site/emission source pairs.
- Obtaining and checking the site information such as location, elevation, and land-use characteristics.
- Completeness of the input meteorological data and accounting for missing data.
- Use of correct options & input parameters.
- Examination of any run-time warning or error messages provided by AERMET.

As part of the application of AERMET, we will:

- Examine any run-time warning or error messages provided by AERMET.
- Check size and content of the AERMOD input files.

3.4. Other Data and Input Files

Other input files required by CMAQ include initial and boundary condition, photolysis rates, and land-use files. These files will be obtained from EPA but reviewed before use in this study.

Tabular summaries of the initial and boundary values for each mercury species as well as ozone and particulate species will be prepared in order to review and quality assure these inputs.

The photolysis rates as calculated using the CMAQ photolysis rates processor (JPROC) will be tabulated and examined.

Plots of the percentage distribution of land-use for each of the CMAQ land-use categories and plots of the ocean designation file will be prepared and examined in order to review and quality assure these inputs.

3.5. Database Management

We will implement a data management plan that emphasizes proper data handling and reliable backup and archival procedures.

For each type of data and/or input file, we will establish a data naming convention such that the contents of the file are easily distinguished and each time a file is modified, the new file is assigned a consistent file name with a higher file extension (e.g., emiss_ptsource_hg_va.a1, emiss_ptsource_hg_va.a2, etc…)

The data and model-ready input files that comprise Virginia Mercury Study input datasets will be stored as electronic files on our computer systems and backed up at regular intervals to magnetic tape.

At the completion of the work in each work area, all data files will be transferred to VDEQ. ICF will retain a copy of all information collected for the project for a period of three years from the contract completion date.

4. Model Application

This section addresses the quality assurance practices that will be followed in applying CMAQ and AERMOD for the Virginia Mercury Study.

4.1. Quality Assurance of CMAQ Input Files and Scripts

Quality assurance of the CMAQ input files and scripts will focus on the following:

- Accuracy and integrity of the scripts used to compile and run the model.
- Use of correct science options & input parameters.
- Use of correct input files (names and dates).
- Assignment of unique and informative output file names and strict adherence to the file naming conventions established for the project.
- Assignment of the output files to the correct directories.

All scripts will be archived so that the parameters, options, and files used for each run can be referenced and checked throughout the project.

4.2. Quality Assurance of CMAQ Runs and Output Files

Quality assurance of the CMAQ runs and output files will include:

- Examination of any run-time warning or error messages provided by CMAQ.
- Checking the name, location, size, and date of all CMAQ output files.
- Ensuring that the files are useable in the postprocessing and plotting programs.
- Examination of the spatial and temporal distribution of pollutant concentrations and deposition amount for the modeling domain and simulation period for reasonableness.
- For sensitivity simulations, examination of the differences in the spatial and temporal distribution of pollutant concentrations and deposition amounts compared to the base simulations.

The last two items will entail the preparation of spatial plots and animations of the simulated concentrations and deposition amounts for mercury and other selected species. Spatial plots will be used to verify consistency with the emissions and meteorological inputs (e.g., rainfall amounts, wind directions). Animations will be used to verify both the spatial and temporal integrity of the output fields. Any unusual or questionable features will be investigated in detail. For sensitivity simulations, difference plots and animations will be prepared.

4.3. Quality Assurance of CMAQ Model-Based Summaries and Displays and Associated Postprocessing Procedures

While the summaries and display of the modeling results will be used to quality assure the CMAQ runs and output files, the analysis products and postprocessing procedures must also be quality assured. This review will focus on:

- Accuracy and integrity of the programs and scripts used prepare the summaries and displays.
- Use of input parameters (times, dates, etc.) and file names.

- Assignment of unique and informative output file names for the summaries and displays and strict adherence to the file naming conventions established for the project.
- Assignment of the summary/display files to the correct directories.

All scripts will be archived so that the parameters, options, and files used in each step of the postprocessing can be linked to the displays and referenced/rechecked as needed.

4.4. Quality Assurance Procedures for AERMOD

To the extent possible, the same quality assurance practices and procedures outlined above for CMAQ will also be used to guide the successful application of AERMOD. Areas specific to quality assurance of the AERMOD application include:

- Setting up an appropriate receptor grid for application of AERMOD.
- Assessing the reasonableness of the source contributions.

4.5. Database Management

We will implement a data management plan that emphasizes proper data handling and reliable backup and archival procedures.

All scripts used in running the models will be saved and archived as part of the documentation of each run.

The output files names will clearly reflect the characteristics (inputs, options, modeled year, etc.) and order of each model run.

The output files will be stored as electronic files on our computer systems and backed up at regular intervals to magnetic tape.

At the completion of the work in each work area, all final output files will be transferred to VDEQ. ICF will retain a copy of all information collected for the project for a period of three years from the contract completion date.

5. Presentations and Documentation

In addition to this quality assurance plan, other project documents include: (1) project work plan, (2) memoranda summarizing the emissions data analysis and literature review tasks, 3) draft and final versions of an emissions data analysis report, 4) modeling protocol, 5) memoranda summarizing the mercury deposition modeling tasks, and 6) draft and final versions of the mercury deposition report.

Several presentations will also be prepared during the course of the study and will present information on project status, technical issues, and interim and final data analysis and modeling results.

5.1. Internal Review

All presentations and reports will need to pass an internal technical and editorial review prior to transmittal to VDEQ. Reports will be professionally produced and both Word and PDF versions will be made available.

5.2. External Review

Prior to preparing the draft emissions data analysis and mercury deposition modeling reports, an outline for each report and various sections of each report will have already been reviewed by VDEQ. Subsequently, draft and final versions of the reports will be prepared.

The emissions data analysis report will be thoroughly inspected to ensure that the following items are included and well explained.

- Review of the point source mercury emissions for Virginia.
- Summary of mercury modeling emissions inventory.
- Future-year estimates of mercury emissions.
- Mercury emissions, data analysis, and modeling literature review.

The mercury deposition modeling report will be thoroughly inspected to ensure that the following items are contained and well explained in the report.

- Conceptual model for mercury deposition.
- Key findings from the sensitivity analysis.
- Assessment of model performance.
- CMAQ modeling methods and results.
- AERMOD modeling methods and results.
- Uncertainties and limitations of the modeling results.
- Accessing and utilizing the modeling datasets.

The project reports will serve as a final quality assurance step for each of the work areas comprising the Virginia Mercury Study. In preparing these documents, ICF and VDEQ contributors will revisit their work and have an opportunity to perform a final check of the input data, results, and conclusions.

The final versions will incorporate and address comments by VDEQ staff and members of the VDEQ peer-review group. The reports will be professionally prepared and edited.